Absence of Lunar Phobic and Lunar Philic Responses to Moon Illumination in Alberta Bats within the Beaverhill Natural Area

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The response to moonlight is variable across species. This may be true for both insects and the diverse Vespertilionid bats that feed on them. This study investigated the impact of varying moon illumination levels on Alberta Vespertilionid bat presence within the Beaverhill Natural Area. It was hypothesized that long-distance migrants, Hoary Bats and Silver-Haired bats, will be more likely to forage under periods of greater moon illumination, while overwintering Big Brown Bats and Alberta *Myotis* species (Alberta Bat…[date unknown]) will not be impacted by moonlight. In the Beaverhill Natural Area, between May 13th and September 12th, weekly surveys were conducted using *Echo Meter Touch 2* to detect ultrasound echolocation calls under the survey night's average moon illumination. Calls were generalized into broad taxa groups to avoid misinterpretation due to difficulty in determining specific species. Results found very weak correlations between the number of bat calls and moon illumination across species, habitat types, and overall totals. More consistent research is needed to better understand species and region-specific responses to moon illumination.

INTRODUCTION

Background

Vespertilionid bats are highly diverse across their habitats with differing preferences to roost and forage in open flatlands, dark caves, and enclosed woods (Birkett et al 2014). *Lasiurus cinereus* is fast flying, adapted for foraging in open spaces such as above forest canopies and along forest edges. In comparison, *Myotis septentrionalis* is adapted for maneuvering within the underbrush of old-growth forests where they glean insects directly off vegetation (Alberta Bat…[date unknown]). Vespertilionid bats use echolocation to aid their detection of prey within different habitats. The bat will produce short, high-frequency ultrasound waves and listen for echoes to create a "sound map" of its surroundings. They can adapt the frequency, duration, and repetition rate of their calls for different purposes, such as navigating and foraging (Surlykke et al 2008; NPS… [date unknown]). Researchers can use recording devices that detect ultrasound echolocation calls to study bats (NPS… [date unknown]).

Animals adapt their behaviours to utilize resources that fluctuate in availability to them spatially and temporally within their habitats (Roeleke et al 2018). The response to moonlight is variable across species (Negraeff and Brigham 1995), including the insects that Vespertilionids may prey upon. Some of these insects are lunar phobic while others are active during well-lit nights (Hecker and Brigham 1999; Roeleke et al 2018). Additionally, nocturnal predators such as owls may become more voracious predators during bright nights, taking advantage of better prey detection (Negraeff and Brigham 1995). As both predator and prey, bats must balance the risk of predation during moonlit nights with the potential for greater insect availability (Roeleke et al 2018). However, in Alberta, bats face relatively few predators, the majority of which are owls. Some studies (Negraeff and Brigham 1995; Hecker and Brigham 1999; Roeleke et al 2018) suggest that fast-flying bats may be fast and agile enough to escape owls, making predation less of a possible threat to foraging during well-lit nights. In bats, the degree of lunar phobia appears to be highly variable depending on the species. A study by Kolkert et al (2020) found that species richness was negatively correlated with increasing moon illumination, but foraging attempts were positively correlated with moon illumination within crop interiors. Negraeff and Brigham (1995) found that moon illumination did not have a significant impact on *M. lucifugus* activity nor a shift from open to covered habitats. This was refuted by Hecker and Brigham (1999) who found that bats on Vancouver Island indeed do not make horizontal habitat shifts but do make shifts in their vertical use of space, occupying the canopy more often during bright nights.

Bat populations worldwide are at risk due to agricultural and urban expansion, light pollution, chemical pollution, wind turbines, and White Nose Syndrome (Kolkert et al 2020; Barré K et al 2022; Gómez-Rodríguez et al 2022; Species Spotlight: Hoary Bat 2022). White Nose Syndrome alone is expected to decimate local bat populations by a mortality rate of about 75% (Gómez-Rodríguez et al 2022). The loss of local bat populations disrupts overall ecosystem dynamics and the ecosystem services they provide, such as natural pest control (Kolkert et al 2020; Gómez-Rodríguez et al 2022). Natural pest control provided by bats is estimated to be worth billions of dollars annually worldwide (Kolkert et al 2020). Understanding the spatial and temporal behaviours of Vespertilionids provides valuable information that can be used to better understand ecosystem dynamics and aid conservation and industrial practices to preserve these animals. The objective of this project was to understand how moonlight exposure impacts the activity of Alberta Vespertilionid bats in rural areas.

Alberta is home to 9 species of bat. *Lasiurus cinereus*, *Lasiurus borealis*, *Lasionycteris noctivagans, Myotis lucifugus, Myotis volans,* and *Myotis ciliolabrum* are known to forage in the open, opting for forest edges and clearings, meadows, and above forest canopies and waterbodies (Thomas 2019; Alberta Bat…[date unknown]; Altenbach JS… [date unknown]a; Altenbach JS… [date unknown]b; Corbett J… [date unknown]). *Myotis septentrionalis* and *Myotis evotis* on the other hand, glean insects directly from vegetation surfaces, choosing to forage within forests (Forbes 2012; Alberta Bat…[date unknown]). *Eptesicus fuscus,* however, are generalists with no preference for open or concealed habitats (Durham M…[date unknown]). Since other studies (Negraeff and Brigham 1995; Hecker and Brigham 1999; Roeleke et al 2018) have suggested that perceived predation is not likely a factor in responses to moon illumination, it was hypothesized that long-distance migrants *Lasiurus cinereus* and *Lasionycteris noctivagans* will be more likely to forage under periods of greater moon illumination since they tend forage and migrate in the open (Alberta Bat…[date unknown]). Additionally, it was hypothesized that overwintering bats *Eptesicus fuscus* and Alberta *Myotis* species (Alberta Bat…[date unknown]) will not be impacted by moonlight due to their short-distance migrations to their winter roosts, exposing them to both low and high moon illumination. This potential impact may be further backed by the tendency of some *Myotis* taxa to forage in the open while others forage where they are concealed by forest vegetation (Thomas 2019; Alberta Bat…[date unknown]; Corbett J [date unknown]; Durham M [date unknown]; Altenbach JS [date unknown]b) averaging the impact of varying moon illumination levels

METHODS AND MATERIALS

Survey Set-Up

This project took place between May 13th and September 12th in the Beaverhill Natural Area, roughly 12km past Tofield, Alberta and at the southeast corner of Beaverhill Lake (Holroyd 2022). While surrounded by farmland, the Natural Area bears an early successional, mixed forest of aspen and balsam with willow alongside wetlands and grasslands (Beaverhill Lake 2004). Survey sites have been previously set up by Beaverhill Bird Observatory (BBO) staff and volunteers throughout a 3km looped route, occupying different habitats of the natural area (Low 2024). Each site has been categorized into 4 habitat types: Tree, Edge, Water, and Grass to represent the interior forest, forest edge, wetland, and grassland, respectively (Low 2024). Each habitat type has 4 sites plus an additional site at the Beaverhill Bird Observatory

(BBO) banding station, making up a total of 17 survey sites (see Figure 1. for map and Appendix A for coordinates). Surveys took place once a week, starting roughly 45 minutes after sunset. As per previous studies in the Beaverhill Natural Area (Low 2024) During the survey, an observer would walk in a loop around the natural area to each station and use a tablet and *Wildlife Acoustics Echo Meter Touch 2 Handheld Detector* to record and identify bat echolocation calls for three minutes at each site (Low 2024). The survey would go in clockwise order one week (start at Grass 4 and end at Tree 1) and counterclockwise order the following week (start at Tree 2 and end at Tree 1). Throughout June and July, some grassland sites were not surveyed due to the lateness of the sunset during that time (Low 2024).

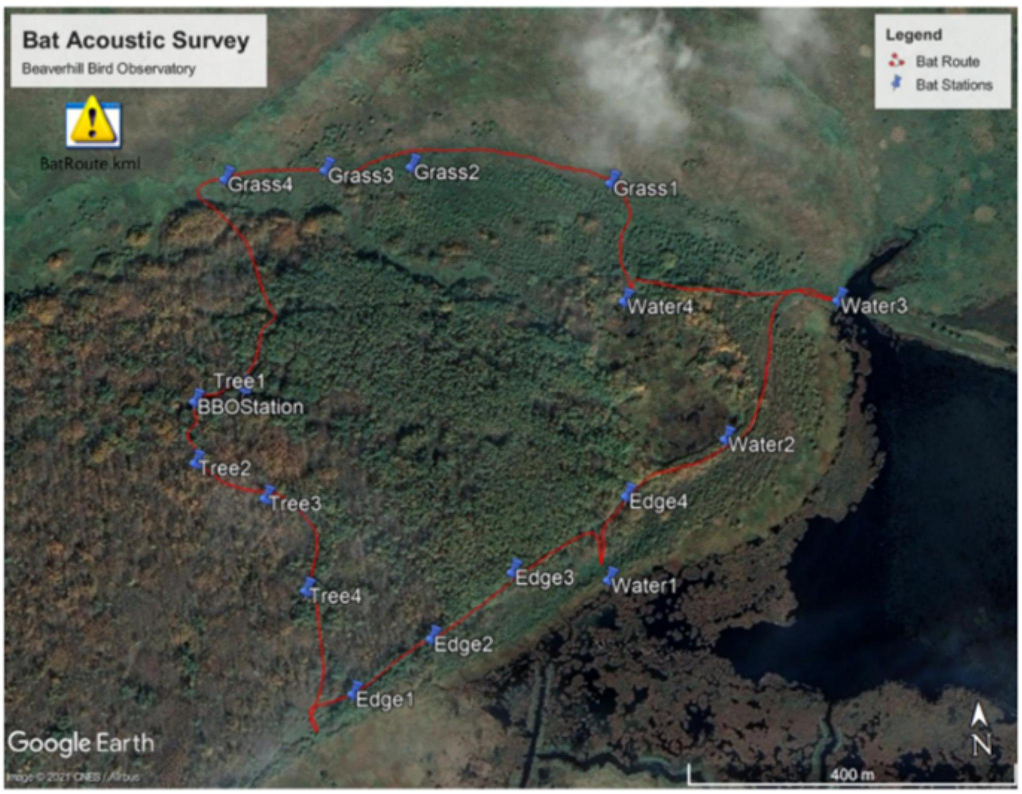

Figure 1. Screenshot of Google Earth Map depicting bat acoustics looped route and survey stations (Low 2024).

Data Collection

Before the beginning of each survey, observers would record the sunset time, temperature, cloud coverage, wind speed and direction, moon phase, and moon illumination and the presence of precipitation (sources of weather parameters can be found in Appendix C). They would then travel to each acoustics site (Figure 1.). At each site, all lights were turned off, and sound was muted to use the *Echo Meter Touch 2 Handheld Detector* to detect echolocation calls for 3 minutes. The start time of these 3 minutes was also recorded. Since it is very difficult for bat echolocation detectors to accurately identify species due to interspecific call similarities (Rydell et al 2017), echolocation calls were counted and divided into the taxa categories *Myotis* genus, EPFULANO representing *Eptesicus fuscus* or *Lasionycteris noctivagans,* LACI representing *Lasiurus cinereus*, and Unknown. Once the observer had finished the route, they would again record the temperature, cloud coverage, wind speed and direction, moon illumination, and the presence of precipitation (Low 2024).

Data Analysis

Weekly bat surveys began on May 13 and ended on September 12. However, only results up to August 28 were included due to an extensive lack of data beyond this point. Using *Microsoft Excel*, each taxon category was totaled per survey night and used to generate a stacked column chart to provide a general understanding of bat taxa occurrences within the Beaverhill Natural Area throughout the summer. Detected bat call totals for each survey night were added to this chart. Additionally, a second stacked column chart was generated to show how many bat calls were detected at each habitat type across each taxa group. Following this, a scatterplot comparing moon illumination and the corresponding total number of detected bat calls for the survey night with that moon illumination was generated. This scatterplot was used to give rise to a trendline and coefficients of determination (R^2) to determine the regression between the number of bat calls and moon illumination. This process was repeated on a second scatterplot that examined the coefficients of determination (R^2) across each individual taxon category and a third time to look at total bat calls at each habitat type compared to moon illumination.

RESULTS

Bats were detected during all surveys (Figure 2). Generally, there was an increase in activity to peak activity from June 24-August 8, followed by a marked decrease in activity (Figure 2). The *Myotis* group made up the overall largest number of detected calls. There were no Hoary Bats (LACI) detected for 2 weeks in July, despite being present for almost every survey night.

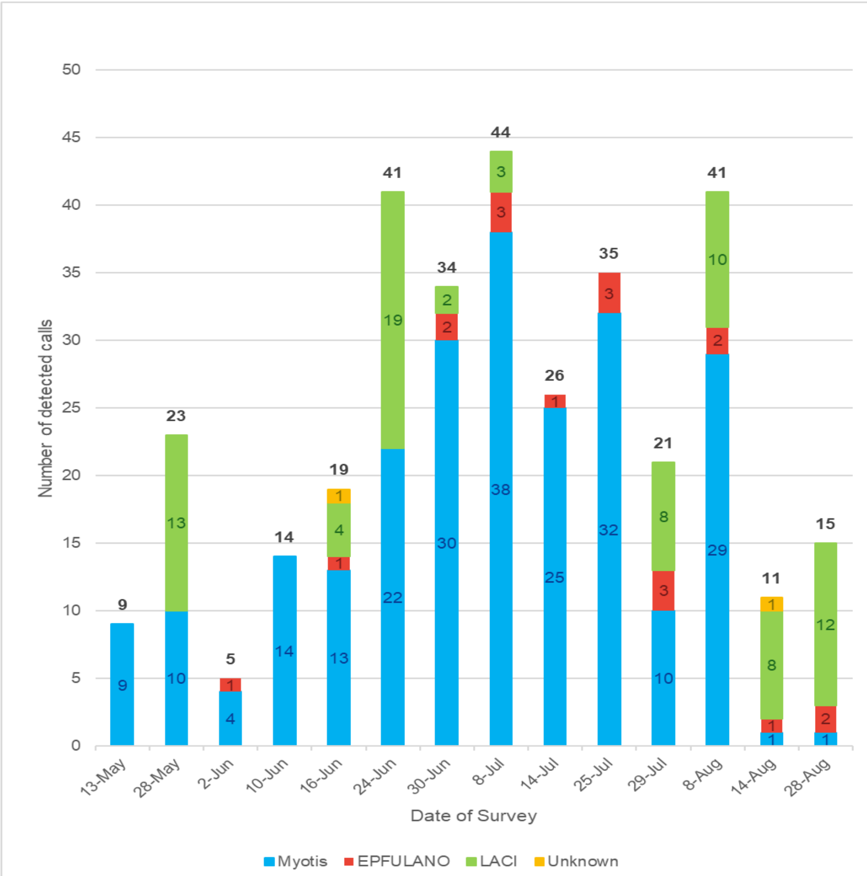

Figure 2. The number of detected calls across each survey night between May13-Aug 28 2025. Each survey night, *Echo Meter Touch 2* was used to detect and record bat calls. Calls were categorized as either Myotis, EPFULANO, LACI, or Unknown. Bolded Values above each column represent nightly totals. (n=14).

Across each habitat type, the greatest number of bats was detected at the BBO survey station, a clearing within the forest interior (Figure 3). Overall, there were 92 detected calls here with equal *Myotis* and LACI detections, but no EPFULANO. The second-highest number of bat calls was found at the Edge Habitats at 84 calls, and there was an equal number of 62 detected bat calls in the Tree and Water habitats. The Grassland habitat had significantly fewer calls with a total of 14.

There was negative variation between the moon illumination and total bat calls (Figure 4; R^2= -0.032; P=0.541). Additionally, there was no relationship between moon illumination and number of *Myotis* or EPFULANO calls (Figure 5; P_{Myotis}=0.834; $P_{EPFULANO}$= 0.666), and a slight negative correlation but no statistical significance for LACI (R2 = 0.2184; P_{LACI}= 0.137) where bat activity decreased as moon illumination increased (Figure 5). Furthermore, there was no relationship between the number of calls detected in each habitat type and moon illumination (Figure 6; $P_{BBO} = 0.387$; $P_{Tree} = 0.312$; $P_{Edge} = 0.629$; $P_{Water} = 0.607$; $P_{Grassland} = 0.702$). However, there was a slight negative relationship between bat activity and moon illumination at the BBO station (R2 = 0.1988; $P_{BBO} = 0.387$), where activity decreased as moon illumination increased. Despite this, moon illumination was not a statistically significant predicting factor.

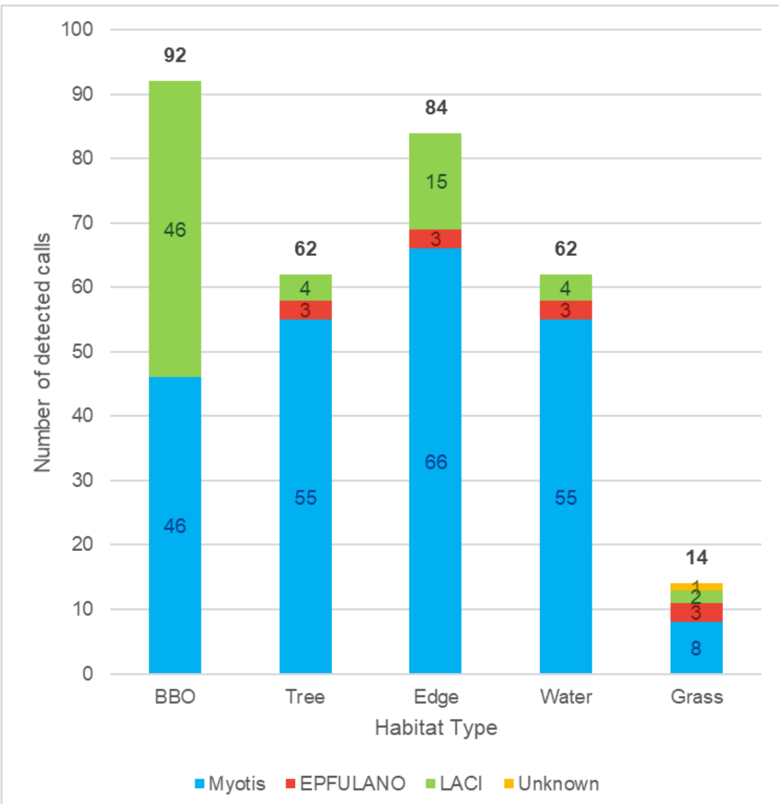

Figure 3. Comparison of the number of detected calls across each habitat type. Each survey night, *Echo Meter Touch 2* was used to detect and record bat calls across 3 sites of each habitat type plus one outside the Beaverhill Bird Observatory banding station. Calls were categorized as either Myotis, EPFULANO, LACI, or Unknown. Bolded Values above each column represent the total number of bat calls at the habitat type. (n=14).

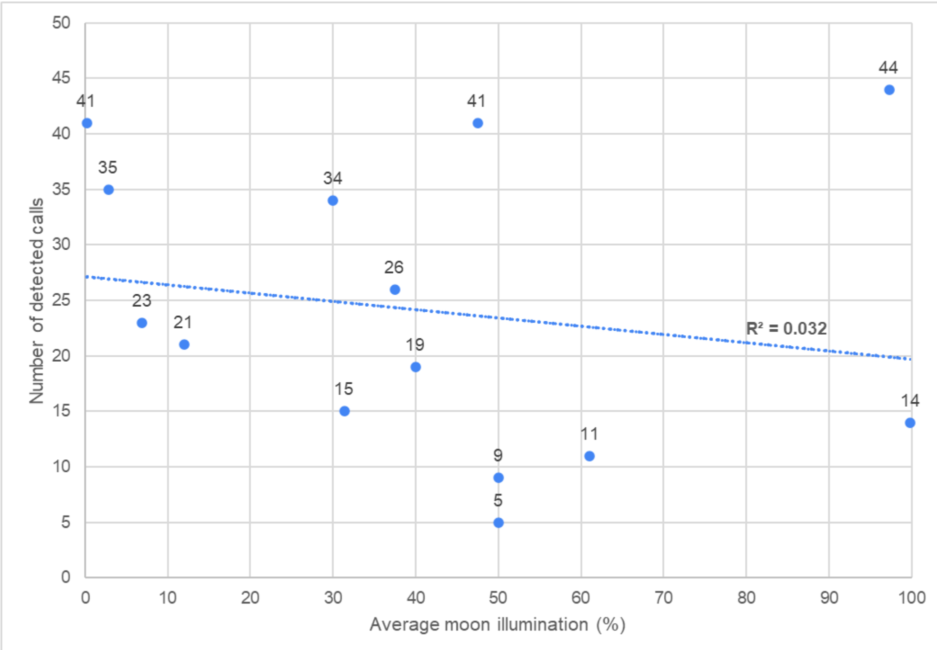

Figure 4. The relationship between the total number of bat calls recorded at different moon illuminations over all survey nights. At the beginning and end of each survey night, moon illumination was recorded and later averaged. The number of calls across each taxa group was totaled and added for each survey night. A trendline was generated after plotting each point and used to generate the coefficient of determination (n=14).

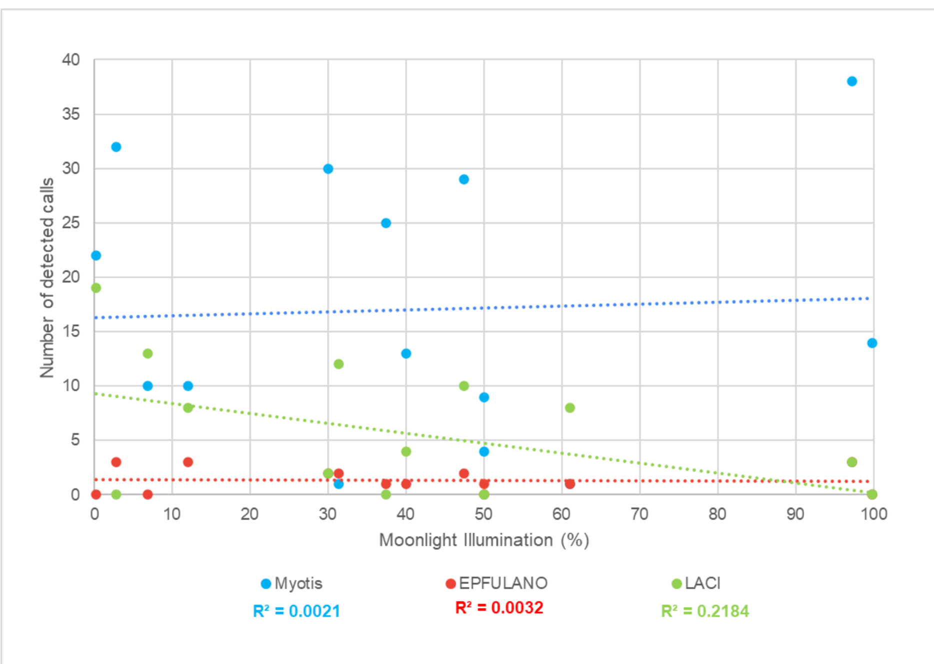

Figure 5. No relationship between the total number of bat calls across different taxa recorded at different moon illuminations over all survey nights. At the beginning and end of each survey night, moon illumination was recorded and later averaged. Calls were

categorized as either Myotis, EPFULANO, LACI, or Unknown. The number of calls across each taxa group were totaled and added for each survey night. A trendline was generated after plotting each point and used to generate the coefficient of determination (n=14).

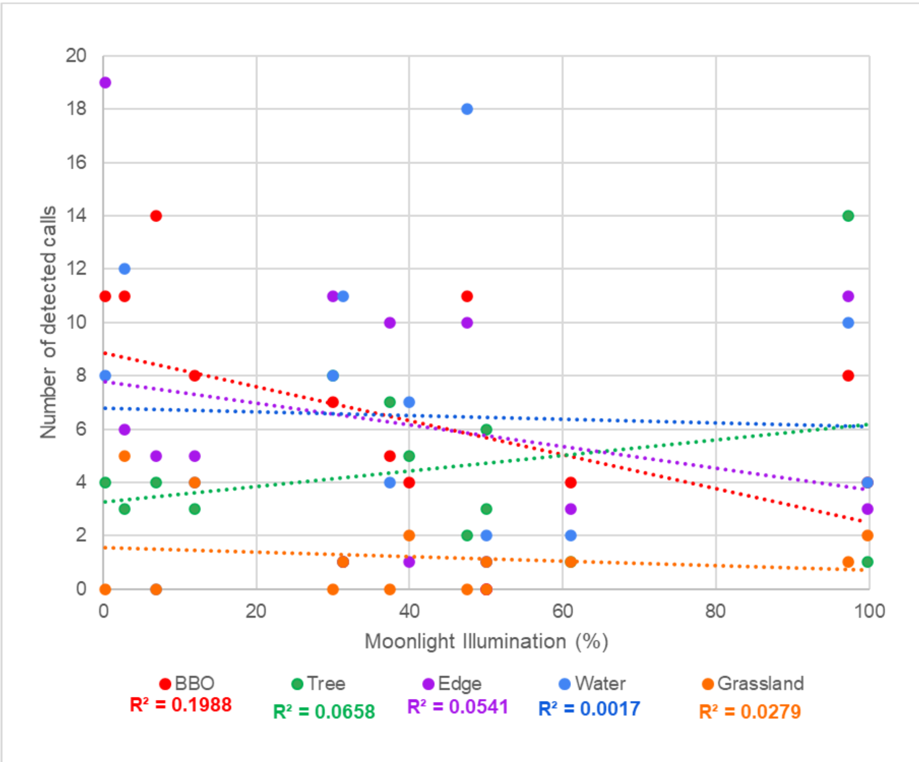

Figure 6. Scatter plot with trendline depicting the total number of bat calls across different habitat types recorded at different moon illuminations over all survey nights. At the beginning and end of each survey night, moon illumination was recorded and later averaged. Each habitat type involved 3 acoustic sites with the exception of BBO which only had 1.. The number of calls across each habitat type were totaled and added for each survey night. A trendline was generated after plotting each point and used to generate the coefficient of determination (n=14).

DISCUSSION

Population Dynamics

Detected bat calls peaked between late June and early August, with most detected calls belonging to species from the *Myotis* genus, followed by Hoary Bats, and Big Brown and Silver-haired bats. This was likely because species belonging to the *Myotis* genus make up 5 of Alberta's 9 bat species. Additionally, *Myotis lucifugus* is the most common bat in Alberta (Alberta Bat…[date unknown]), and *Myotis* were frequently observed within bat boxes throughout the area. The trend in increasing *Myotis* detections in early June and decreasing detections in late July and August is likely explained by general *Myotis* population trends. Early in the summer, females are pregnant. By June, juvenile *Myotis lucifugus* are mobile but do not disperse until late July and early August (Schorr and Siemers 2021).

Habitat Use

The habitats with the most detected bat calls were the BBO acoustic station and the Edge habitats. The BBO acoustic station contained cabins, a large house-like observatory with movement-activated lights, as well as a movement-activated light near the outhouse. While these lights are seldom activated later in the night, they were easily activated by surveyors and observatory occupants at the beginning of bat surveys. These artificial lights may provide easy access to insects prone to disrupted flight orientation (Fabian et al 2024) but still abundant coverage from the surrounding foliage. *Myotis* occupy three bat boxes in the clearing including a large maternity colony. *Myotis* are also known to roost in buildings (Alberta Bat…[date unknown]), so foraging near where they roost and where predators such as owls may be averse to the motion-activated lights and foot traffic around the observatory may help preserve energy. However, more research would be needed to investigate this, as other studies have shown that *Myotis* tend to be light-averse (Seewagan et al 2023) and that artificial lighting may only be attractive to bats on a local scale (Mariton et al 2023). However, simultaneous openness and coverage of the BBO station and Edge habitats coincide with the preference of *Lasiurus cinereus*, *Myotis lucifugus*, *Myotis volans*, and *Myotis ciliolabrum* to forage in semi-open to open areas (Thomas 2019; Alberta Bat…[date unknown]; Altenbach JS… [date unknown]b; Corbett J… [date unknown]).

There were very few bats detected within the grassland habitats. However, these results are skewed as the grassland was not consistently surveyed mid-summer due to the lateness of the sun setting (Low 2024). Despite this, when surveyed, the grassland habitat sites often did not yield very many bat detections. It is possible that even for open-space foraging bats, edges and forest canopies are preferred as they provide room for flight maneuvers as well as coverage, whereas open grasslands are very exposed, making bats vulnerable to predation.

Moonlight Responses

Overall, there was a very weak regression between moon illumination and bat detection across all species, indicated by a low coefficient of determination value. This was also true between taxa groups. This supports the hypothesis that overwintering bats *Eptesicus fuscus* and Alberta *Myotis* species, would not be heavily impacted by moon illumination. However, it does not support the hypothesis that long-distance migrants *Lasiurus cinereus* and *Lasionycteris noctivagans* would be more likely to forage under periods of greater moon illumination, as the EPFULANO group had a coefficient of correlation less than 0.01, and the LACI group had a small coefficient of determination that showed that Hoary bats had slightly more detections on nights of lower moon illumination. These results contrast with Seewagan et al (2023), who found that *Myotis lucifugus* seems to be very artificial light-averse, while *Lasiurus cinereus* tends to be more tolerant when exposed to artificial light at night. Because of this, artificial light and natural moonlight may have very different impacts on bat activity, especially as moonlight is more heavily scattered by particles in the atmosphere.

In a similar way to taxa differences, there was a very weak correlation between moon illumination and habitat use. However, this was only from a ground-level perspective. One limitation of this study was the inability to investigate vertical habitat changes in response to moon illumination, as Hecker and Brigham (1999) did. Some insects exhibit light attraction while others exhibit light repulsion (Fabian et al 2024). It is possible that the bats exhibited prey switching, opting for lunar philic or lunar phobic insect prey depending on the moon illumination for that night, hence explaining why moon illumination did not seem to have a strong impact on bat detection. Furthermore, it is possible that northern bat species may not display lunar phobia as strongly as southern species due to longer nights and fewer predators compared to southern regions (Apoznański et al 2024). A study by Apoznański et al (2024) found that European Vespertilionid bats do not exhibit lunar phobia during autumn swarming. They suggested that during autumn swarming in European Vespertilionids, the bats are not foraging but rather prioritizing expression of social behaviours essential to mating to ensure the reproduction of the species (Apoznański et al 2024). While autumn swarming was not observed in this study, similar principles of urgency for reproduction may apply, at least for some months of the summer. Bat mothers may experience some urgency in nourishing their pups until self-sufficient, risking foraging under high moonlight conditions to do so.

Limitations

As mentioned earlier, surveyors were limited to the ground and were unable to detect bats across a vertical scale. Additionally, although the *Echo Meter Touch 2* can suggest which specific species made particular calls, its reliability is questionable, hence why taxa had to be sorted into broad groups for analysis. Certain aspects of the study were subjective, such as the determination of cloud coverage by visual examination. The sunset was very late in June and July, so grassland sites were not surveyed for some weeks during this time, potentially impacting the analysis of the grassland. Lastly, more than one observer conducted surveys each week, so surveys were not consistently conducted on the same days.

Future Directions

There is high variability across studies regarding species responses to general and habitat-specific moon illumination. More research is needed to better understand this phenomenon in a region and species-specific manner. This research could be aided by improved echolocation detectors to yield more accurate results in determining species (Rydell et al 2017). Understanding bat behaviours more precisely can be used to preserve populations, helping to alleviate widespread challenges such as White Nose Syndrome, pollution, and habitat loss and fragmentation (Barré K et al 2022). For instance, the response to moonlight can inform the timing or avoidance of pesticide sprays at night, thereby helping to avoid bioaccumulation and maximizing natural pest control (Kolkert et al 2020).

CONCLUSION

The most bats were detected during the mid-summer months of late June to July, tapering as the season changed in late August. This study found that bats within the Beaverhill Natural Area show preferences for semi-open environments such as forest clearings and forest edges but not open habitats such as grasslands. Additionally, there was no strong evidence for lunar phobia or philia between species and between habitats, with only slightly larger regression occurring in Hoary bats and the BBO acoustic station. All other species had no strong preferences for varying moon illumination levels, and there were no large differences between habitat types in regard to moon illumination. Future studies should investigate the impact of moon illumination further, to try and better understand heterogeneity between studies, filling in the gaps to better aid conservation.

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Appendix

Appendix A: Table showing acoustic survey station coordinates

Station Name	Latitude	Longitude
BBO	53.38057506	-112.5270413
Edge 1	53.37733604	-112.524331
Edge 2	53.37789897	-112.522864
Edge 3	53.37858796	-112.521335
Edge 4	53.37936597	-112.519192
Grass 1	53.38278897	-112.519249
Grass 2	53.38305099	-112.522911
Grass 3	53.38305099	-112.524498
Grass 4	53.38299701	-112.526349
Tree 1	53.38069903	-112.526129
Tree 2	53.37990702	-112.527069
Tree 3	53.37949304	-112.525806
Tree 4	53.37847497	-112.525126
Water 1	53.37845997	-112.519579
Water 2	53.37994197	-112.517331
Water 3	53.38140696	-112.515157
Water 4	53.38149003	-112.519084

Appendix B: Table showing Echo Meter Touch 2 settings used for bat call detection and recording.

Setting name	Setting specifications	Setting location
Spectrogram display	Spectrogram should take up almost all of the screen (wave form should be small)	LIVE MODE
Spectrogram frequency axis	**0 – 128 kHz (maxed out y-axis)**	**LIVE MODE**
Spectrogram time axis	0 – 150 ms	LIVE MODE
Frequency reference line	30 kHz (separate HighF from LowF bats)	LIVE MODE
To record bats	**Big red button ("M" should be greyed out and the big red button should be activated)**	**LIVE MODE**
Listen to bat	"RTE" (use buttons on tablet to turn volume up and down while recording)	LIVE MODE
View bats	Compressed time (three lines should be close together and the spectrogram should be moving slowly)	LIVE MODE
Spectrogram Brightness	20ish (change as needed depending on ambient noises etc.)	Spectrogram Settings (cog wheel in bottom right)
Spectrogram Contrast	20ish (change as needed depending on ambient noises etc.)	Spectrogram Settings (cog wheel in bottom right)
Trigger Minimum Frequency	**16 kHz**	**Spectrogram Settings (cog wheel in bottom right)**
Set auto-id species list	North America → Alberta → EPFU, LANO, LABO, LACI, MYLU, MYSE, MYVO (uncheck MYCI and MYEV)	AUTO ID SELECTION
Audio Division Ratio	1/20	ADVANCED SETTINGS
Nightly Sessions Mode	**ON**	**ADVANCED SETTINGS**
Save Noise Files	OFF	ADVANCED SETTINGS
Real-Time Auto ID	ON	ADVANCED SETTINGS
Auto-ID Sensitivity	Balanced	ADVANCED SETTINGS
Trigger Sensitivity	**Medium**	**ADVANCED SETTINGS**
Trigger Window	**2 sec**	**ADVANCED SETTINGS**
Max Trigger length	**15 secs**	**ADVANCED SETTINGS**

Appendix C: Table providing sources for Weather Parameters

Weather Parameter	Source
Temperature	The Weather Network; Tofield; https://www.theweathernetwork.com/en/city/ca/alberta/tofield/current
Cloud Coverage	Determination of what percentage of the sky was covered through subjective visual observation
Precipitation	Subjective determination by prescence of precipitation during survey
Wind Speed	BBO Banding Station Weather Detector; converted to Beaufort Wind Scale
Wind Direction	BBO Banding Station Weather Detector
Moon Phase	Time and Date; Tofield: https://www.timeanddate.com/astronomy/@6167254
Moon Illumination	Time and Date; Tofield: https://www.timeanddate.com/astronomy/@6167254